**Indicator: Blood Persistent Organic Pollutants (POPs) Level (336)**

Persistent organic pollutants (POPs) are manmade organic chemicals that remain in the environment for years or decades. Some POPs are toxic; others are not. Toxic POPs are of special concern because they often remain toxic for decades or longer. The more persistent a toxic chemical is, the greater the probability for human exposure over time. Because they circulate globally long after their release into the environment, POPs released in one part of the world are often detected in regions far from the original source (EPA, 2004a).

One of the major sources of POPs exposure among the general population is food. Food contamination begins with contaminated soil and/or plants but is of greatest concern to humans as the POPs move up the food chain into animals. Because POPs are stored, especially in fat, they accumulate and increase in concentration with each trophic level. Therefore, foods such as dairy products, eggs, animal fats, and some types of fish are more likely to contain greater concentrations of POPs than fruits, vegetables, and grains. POPs have been linked to adverse health effects such as cancer, nervous system damage, reproductive disorders, and disruption of the immune system in both human and animals (EPA, 2004a).

This indicator presents data from CDC's National Health and Nutrition Examination Survey (NHANES) 1999-2000. NHANES is a series of surveys conducted by CDC's National Center for Health Statistics (NCHS) that is designed to collect data on the health and nutritional status of the civilian, non-institutionalized U.S. population using a complex, stratified, multistage, probability-cluster design. Beginning in 1999, NHANES became a continuous and annual national survey; biomonitoring for certain environmental chemicals also was implemented. These data are presented here as a baseline with the intent of reporting trends in the future. Blood serum levels of POPs or their metabolites are presented for NHANES participants age 12 years or older. This indicator includes the following three broad classes of POPs:

- Organochlorine pesticides
- Polychlorinated dibenzo-p-dioxins (dioxins) and polychlorinated dibenzo-p-furans (furans)
- Polychlorinated biphenyls (PCBs)

**Organochlorine pesticides** were first introduced in the 1940s. Because of their environmental persistence, EPA banned most uses of these chemicals during the 1970s and 1980s. However, many other countries still produce and/or use organochlorines. These fat-soluble chemicals are most commonly absorbed through fatty foods. This indicator includes five organochlorine pesticides that were measured in NHANES 1999-2000; data on three others (aldrin, dieldrin, and endrin) will be available with the release of results from NHANES 2001-2002 (CDC, 2005). Acute exposure to high concentrations of organochlorine pesticides has demonstrated effects to the central nervous system (Reigart and Roberts, 1999),

- **Chlordane and heptachlor**. EPA banned these pesticides in 1988. Within the body, chlordane is metabolized to oxychlordane and *trans*-nonachlor, and heptachlor is metabolized to heptachlor epoxide. (CDC, 2003). Chlordane was commonly used against termites and on some agricultural crops and heptachlor was used primarily against soil insects and termites (Ritter et al.).
- **DDT**. Dichlorodiphenyltrichlorethane, or DDT, was banned in the United States in 1973 but is still produced in other countries, where it is used primarily to control mosquitoes. In the body or the environment, DDT breaks down to DDE (dichlorodiphenyldichloroethylene), a more persistent chemical. DDT or DDE in the human body may reflect either a relatively recent exposure or cumulative past exposures (CDC, 2003).

- **Hexachlorobenzene** (HCB) was commonly used as a pesticide until 1965. HCB was also used in the past as a fungicide to protect wheat seeds, and for a variety of industrial purposes, including rubber, aluminum, dye production and wood preservation (EPA, 2004b). EPA canceled registered use in 1984; however, HCB is still formed as a by-product during manufacturing of other chemicals and pesticides (EPA, 2004b).
- **Mirex** has not been produced or used in the United States since 1978. It was used primarily in the southern United States to control fire ants. The primary source of exposure is dietary, most often through consumption of fish (EPA, 2004c).

**Dioxins and furans** are similar classes of chlorinated aromatic chemicals, usually generated as pollutants or by-products. In the environment, dioxins and furans occur as a mixture of about 20 compounds (termed "congeners"). Half-lives of these congeners range from roughly 3 to 19 years (CDC, 2003). Human exposure occurs primarily through food; other sources of exposure include industrial accidents, burning of PCBs contaminated with dioxins and furans, burning of many plastics such as PVC, and spraying or unintended releases of contaminated herbicides such as Agent Orange. The detection of dioxins and furans in human serum can reflect either recent or past exposures (CDC, 2003).

Human health effects associated with dioxins and furans are wide-ranging. The effects of individual congeners are difficult to determine since most people are exposed to mixtures of several congeners. However, overall health effects include liver disorders, fetal injury, porphyria (a condition resulting in abnormal metabolic function), elevated lipid levels, chloracne, hormonal changes, neurologic damage, and immunogenic changes. The dioxin congener TCDD (2,3,7,8-tetrachlorodibenzo-*p*-dioxin) is the most toxic form of dioxin and it is classified as a known human carcinogen (IARC, 1997). The half-life of TCDD is estimated to be around 7 years (CDC, 2003).

**Polychlorinated biphenyls** (PCBs) are chlorinated aromatic hydrocarbons used in a variety of industries as electrical insulating and heat exchange fluids. PCBs are composed of mixtures of up to 209 different chlorinated congeners. United States production of PCBs peaked in the early 1970s; PCBs were banned in 1979. Sources of exposure for the general population include releases from waste sites and fires involving transformers, ingestion of foods contaminated by PCBs, and migration from packaging materials. PCBs typically accumulate in fatty tissues (ATSDR, 2000).

The detection of PCBs in human serum can reflect either recent or past exposures. PCBs with higher degrees of chlorination persist in the human body from several months to years after exposure. Coplanar and mono-ortho substituted PCBs exhibit health effects similar to dioxins. The human health effects of PCBs include changes in liver function, elevated lipids, and gastrointestinal cancers (CDC, 2003).

**What the Data Show**

**Organochlorine pesticides**. Table 336Organochlorine presents the geometric means for serum concentrations, lipid adjusted, for the selected organochlorine pesticide metabolites. The overall geometric mean for DDE (metabolite for DDT) was 260 ng/g of lipid. The geometric mean for *trans*-nonachlor (metabolite for chlordane) was 18.3 ng/g of lipid. Metabolites for heptachlor, HCB, and mirex were not measured with sufficient frequency above the limit of detection to calculate a geometric mean.

Geometric mean serum concentrations of *p, p'*-DDE were compared among demographic groups after adjustment for the covariates of race/ethnicity, age, and gender. The 12-19 year age group had less than half the serum DDE level of the 20 years-and-older age group (CDC, 2003). The adjusted geometric mean level in Mexican Americans was 653 ng/g, about three times higher than levels in non-Hispanic Whites and two times higher than non-Hispanic Blacks. It is unknown whether differences in geometric mean

serum DDE concentrations between ages or races/ethnicities represent differences in exposure, body size relationships, or metabolism (CDC, 2003).

**Dioxins and furans**. Human serum lipid-based levels of overall dioxins and furans have decreased by an estimated 80% since the 1980s and the low NHANES 1999-2000 values support that estimation (CDC, 2003). Within the 12 years-and-older subsample of NHANES 1999-2000, none of the six dioxin or nine furan congeners measured in blood serum were measured with sufficient frequency above the limit of detection to calculate a geometric mean. TCDD had a detection rate of 0.7% (CDC, 2003). Five dioxin and four furan congeners had a detection rate above 5%. The more highly chlorinated dioxin and furan congeners were the main contributors to the human body burden (CDC, 2003).

**PCBs**. Within the NHANES 1999-2000 subsample, none of the 28 PCB congeners were measured in blood serum with sufficient frequency above the limit of detection to calculate a geometric mean. The frequency of detection of the eight mono-ortho substituted PCBs ranged from 2 to 47% (CDC, 2003). Coplanar PCB congeners 169 and 126, which exhibit dioxin-like toxicity, had a detection rate above 5% (CDC, 2003).

**Indicator Limitations**

- NHANES selects a representative sample of the civilian, non-institutionalized population in the United States using a complex, stratified, multistage, probability-cluster design. Beginning in 1999, NHANES became a continuous and annual national survey. With only 2 years of data in NHANES 1999-2000, instead of the 6-years for NHANES III (1988-1994), some differences exist that may limit the underlying data with respect to completeness or representative of coverage.
    - The sample size is smaller and the number of geographic units in the sample is more limited. The current 1999-2000 NHANES survey is nationally representative but it is subject to the limits of increased sampling error due to (1) the smaller number of individuals sampled in the annual sample and (2) the smaller number of Primary Sampling Units (PSUs) [see description below] available for each annual sample. Therefore, the sample size for any 1-year period is relatively small, possibly resulting in large variability for U.S. population estimates, especially those for narrowly defined demographic groups or other specific subgroup analyses.
    - For NHANES 1999-2000, the first stage of selection was the primary sampling unit (PSU) level. PSUs were defined as single counties. For a few PSUs, the county population was too small and those counties were combined with geographically contiguous counties to form a PSU. The 1999-2000 NHANES sample is selected from a relatively small number of PSUs compared to NHANES III. With a small number of PSUs, variance estimates that account for the complex design may be relatively unstable, a factor which introduces a higher level of uncertainty in the annual estimates.
    - NHANES is designed to increase precision by combining data across calendar years. Because of the relatively small sample size in 1999 and 2000, analytical data for just one or two survey participants may be weighted heavily and greatly influence the mean value reported.
    - The number of geographic sites sampled each year is small and environmental exposures may vary geographically; thus producing environmental exposure estimates by geographic region using the NHANES data set is of limited value.
- The measurement of an environmental chemical in a person's blood or urine does not by itself mean that the chemical has caused or will cause harmful effects.
- Generally recognized guidelines for serum levels of organochlorine pesticides and dioxin, furan, and PCB congeners have not yet been established.

**Data Sources**

Centers for Disease Control and Prevention. 2003. Second National Report on Human Exposure to Environmental Chemicals. (Accessed November 21, 2004)
http://www.cdc.gov/exposurereport/2nd/pdf/secondner.pdf

**References**

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**Graphics**

Table 336Organochlorine. Geometric mean and selected percentiles of selected serum organochlorine pesticide metabolites, lipid adjusted levels (ng/g)* for the United States population, aged 12 years and older, National Health and Nutrition Examination Survey (NHANES), 1999-2000

| | Sample Size | Geometric Mean | 10th | 25th | 50th | 75th | 90th |
|---|---|---|---|---|---|---|---|
| Chlordane | | | | | | | |
| Oxychlordane | 1661 | NC | <LOD | <LOD | <LOD | 20.6 | 34.4 |
| *trans*-Nonachlor | 1933 | 18.3 | <LOD | <LOD | 17.8 | 31.9 | 55.1 |
| Heptachlor | | | | | | | |
| Heptachlor Epoxide | 1589 | NC | <LOD | <LOD | <LOD | <LOD | 15.3 |
| DDT/DDE | | | | | | | |
| *p, p'*-DDE | 1964 | 260 | 74.4 | 114 | 226 | 537 | 1150 |
| *p, p'*-DDT | 1679 | NC | <LOD | <LOD | <LOD | <LOD | <LOD |
| *o, p'*-DDT | 1669 | NC | <LOD | <LOD | <LOD | <LOD | <LOD |
| Hexachlorobenzene | 1702 | NC | <LOD | <LOD | <LOD | <LOD | <LOD |
| Mirex | 1853 | NC | <LOD | <LOD | <LOD | <LOD | <LOD |

* ng/g = nanograms/gram of lipid or parts-per-billion on a lipid weight basis
<LOD= Less than the limit of detection of the analytical method.
NC= Not calculated – Proportion of results below limit of detection was too high to provide a valid result.
Source: Centers for Disease Control and Prevention. Second National Report on Human Exposure to Environmental Chemicals. January 2003. (Accessed November 21, 2004) http://www.cdc.gov/exposurereport/2nd/pdf/secondner.pdf

**R.O.E. Indicator QA/QC**

**Data Set Name:** BLOOD POPS LEVEL
**Indicator Number:** 336 (90063)
**Data Set Source:** CDC, NHANES
**Data Collection Date:** ongoing
**Data Collection Frequency:** 2 year cycle
**Data Set Description:** Blood POPs Level
**Primary ROE Question:** What are the trends in biomeasures of exposure to common environmental pollutants including across population subgroups and geographic regions?

**Question/Response**

**T1Q1** Are the physical, chemical, or biological measurements upon which this indicator is based widely accepted as scientifically and technically valid?

Yes. Blood samples were collected and processed in accordance with the methods indicated in the NHANES Specimen Collection and Laboratory/Medical Technologists Procedures Manual (LPM). See: http://www.cdc.gov/nchs/data/nhanes/blood.pdf
http://www.cdc.gov/nchs/data/nhanes/LAB1-6.pdf

**T1Q2** Is the sampling design and/or monitoring plan used to collect the data over time and space based on sound scientific principles?

Yes. NHANES is designed to provide statistically representative national averages. Starting with NHANES 1999, the survey is conducted annually. A subsample of participants aged 12 years and older in NHANES 1999-2000 were measured for blood levels of the persistent organic pollutant chemicals. Subsamples were randomly selected within the specified age range to be a representative sample of the U.S. population. The measurements produced by NHANES for this indicator were used in the Second National Report on Human Exposure to Environmental Chemicals published by the National Center for Environmental Health in 2003.
http://www.cdc.gov/exposurereport/2nd/pdf/secondner.pdf

**T1Q3** Is the conceptual model used to transform these measurements into an indicator widely accepted as a scientifically sound representation of the phenomenon it indicates?

Not applicable

**T2Q1** To what extent is the indicator sampling design and monitoring plan appropriate for answering the relevant question in the ROE?

This indicator is based on a national probability-based sampling design and is deemed of sufficient quality for generalization to the nation. The samples for 1999-2000 were used for this analysis. Quality assurance measures were in place. Beginning in 1999, NHANES became a continuous and annual survey. The sampling plan for each year follows a complex, stratified, multistage, probability-cluster design to select a representative sample of the civilian, noninstitutionalized population. Every year, approximately 7,000 individuals, of all ages, are interviewed in their homes; of these, approximately 5,000 complete the health examination component of the survey. The survey sample size for NHANES 1999-2000 is 9,965 (http://www.cdc.gov/nchs/data/nhanes/gendoc.pdf).

**T2Q2** To what extent does the sampling design represent sensitive populations or ecosystems?

The current sampling design includes oversampling of African Americans, Mexican Americans, adolescents (12-19 year olds), older Americans (60 years of age and older), and pregnant women to produce more reliable estimates for these groups.

**T2Q3** Are there established reference points, thresholds or ranges of values for this indicator that unambiguously reflect the state of the environment?

This indicator simply provides information that exposure to a selected persistent organic pollutant has occurred. Generally recognized guidelines for serum levels of POPs have not been established. The measurement of an environmental chemical in a person s blood or urine does not by itself mean that the chemical has caused or will cause harmful effects. More research is needed to identify at which POPs constitute a health concern. As reported in Second National Report on Human Exposure to Environmental Chemicals published by the National Center for Environmental Health in 2003. http://www.cdc.gov/exposurereport/2nd/pdf/secondner.pdf

**T3Q1** What documentation clearly and completely describes the underlying sampling and analytical procedures used?

Documentation for NHANES 1999-2000 is found on NCHS/CDC website at the following URL: http://www.cdc.gov/nchs/about/major/nhanes/nhanes99_00.htm#Laboratory%20Files The following provides more specific examples: The Addendum to the NHANES III for the 1999-2000 dataset clearly outlines the 1999-2000 sampling design and recommends analytic procedures. http://www.cdc.gov/nchs/data/nhanes/guidelines1.pdf http://www.cdc.gov/nchs/data/nhanes/nhanes3/nh3gui.pdf The Second National Report on Human Exposure to Environmental Chemicals published by the National Center for Environmental Health in 2003 more generally describes the NHANES 1999-2000 sampling plan. http://www.cdc.gov/exposurereport/2nd/pdf/secondner.pdf The NHANES 1999-2000 subsampling webpage clearly describes the subsampling methods used and how subsampled data should be analyzed http://www.cdc.gov/nchs/about/major/nhanes/subsample.htm as do the Weighting Notes posted on the NHANES website http://www.cdc.gov/nchs/data/nhanes/frequency/weights%20to%20usev6.pdf

**T3Q2** Is the complete data set accessible, including metadata, data-dictionaries and embedded definitions or are there confidentiality issues that may limit accessibility to the complete data set?

For the most part, Individual level data are available, but data access limitations do exist for some variables due to confidentiality issues.
http://www.cdc.gov/nchs/about/major/nhanes/nhanes99_00.htm#Laboratory%20Files

**T3Q3** Are the descriptions of the study or survey design clear, complete and sufficient to enable the study or survey to be reproduced?

Yes. The Addendum to the NHANES III for the 1999-2000 dataset clearly outlines the 1999-2000 sampling design and recommends analytic procedures.
http://www.cdc.gov/nchs/data/nhanes/guidelines1.pdf
http://www.cdc.gov/nchs/data/nhanes/nhanes3/nh3gui.pdf

**T3Q4** To what extent are the procedures for quality assurance and quality control of the data documented and accessible?

The quality assurance plans for NHANES 1999-2000 are available from the Division of Data Dissemination, NCHS, 6525 Belcrest Rd. Hyattsville, MD, 20782-2003. Tel. 301-458-4636. Internet: http://www.cdc.gov/nchs/about/quality.htm

**T4Q1** Have appropriate statistical methods been used to generalize or portray data beyond the time or spatial locations where measurements were made (e.g., statistical survey inference, no generalization is possible)?

Yes. The NHANES 1999-2004 survey is designed to be annually nationally representative of the U.S. citizen, non-institutionalized population. (see page 11 of the addendum linked below) http://www.cdc.gov/nchs/data/nhanes/guidelines1.pdf

**T4Q2** Are uncertainty measurements or estimates available for the indicator and/or the underlying data set?

Yes. (see pages 11-19 of the addendum linked below) http://www.cdc.gov/nchs/data/nhanes/guidelines1.pdf

**T4Q3** Do the uncertainty and variability impact the conclusions that can be inferred from the data and the utility of the indicator?

NHANES selects a representative sample of the civilian, non-institutionalized population in the United States using a complex, stratified, multistage, probability-cluster design. Beginning in 1999, NHANES became a continuous and annual national survey. With only 2 years of data in NHANES 1999-2000, instead of the 6-years for NHANES III (1988-1994), some differences exist that may limit the underlying data with respect to completeness or representative of coverage. The sample size is smaller and the number of geographic units in the sample is more limited. The current 1999-2000 NHANES survey is nationally representative but it is subject to the limits of increased sampling error due to (1) the smaller number of individuals sampled in the annual sample and (2) the smaller number of Primary Sampling Units (PSUs) [see description below] available for each annual sample. Therefore, the sample size for any 1-year period is relatively small, possibly resulting in large variability for U.S. population estimates, especially those for narrowly defined demographic groups or other specific subgroup analyses. For NHANES 1999-2000, the first stage of selection was the PSU-level. The PSUs were defined as single counties. For a few PSUs, the county population was too small and those counties were combined with geographically contiguous counties to form a PSU. The 1999-2000 NHANES sample is selected from a relatively small number of PSUs compared to NHANES III. With a small number of PSUs, variance estimates that account for the complex design may be relatively unstable, a factor which introduces a higher level of uncertainty in the annual estimates. NHANES is designed to increase precision by combining data across calendar years. Because of the relatively small sample size in 1999 and 2000, analytical data for just one or two survey participants may be weighted heavily and greatly influence the mean value reported. The number of geographic sites sampled each year is small and environmental exposures may vary geographically; thus producing environmental exposure estimates by geographic region using the NHANES data set is of limited value.
http://www.cdc.gov/nchs/about/major/nhanes/subsample.htm)

**T4Q4** Are there limitations, or gaps in the data that may mislead a user about fundamental trends in the indicator over space or time period for which data are available?

As subsequent years are added to this survey, estimates will become more stable. However, with the laboratory data, there is no guarantee that an environmental chemical will be measured from year to year. It is unknown whether differences between ages, genders, or races/ethnicities represent differences in exposure, body-size relationships, or metabolism. Generally recognized guidelines for serum levels of these chemicals have not been established. Measurement of these chemicals in the blood can reflect either a relatively recent exposure or a cumulative past exposure over time because of the persistent nature of these chemicals. The measurement of an environmental chemical in a person s blood or urine does not by itself mean that the chemical has caused or will cause harmful effects.